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How blanching and drying affect the colour and functional characteristics of yam (*Dioscorea cayenensis-rotundata*) flour

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Abstract

Colour and texture are important features of amala, a traditional thick paste obtained from dry yam flour. Tubers from eight yam cultivars were blanched at 65 °C for 20 min and dried at 40 °C for 5 days to test biochemical, thermal and pasting changes occurring during traditional yam flour processing. Blanching reduced peroxidase activity and drying reduced polyphenoloxidase activity, but total phenol content and the brown index of flour and of amala increased dramatically during the latter operations. The brown index of amala was significantly correlated with the total phenol content of the flour ($r = 0.84$) and the peroxidase activity of the fresh tubers ($r = 0.75$). Amylose content and starch gelatinization enthalpy remained stable. For all cultivars, drying significantly increased the onset gelatinization temperature, suggesting the occurrence of starch annealing. The latter leads to a reduction in swelling power and solubility during pasting, and hence to a lower paste viscosity.

Keywords: Yam; Phenols; Polyphenoloxidase; Peroxidase; Blanching; Viscosity

1. Introduction

Yams (*Dioscorea* spp.) are an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of west Africa. To overcome the high perishability of fresh yam tubers, due to their high moisture content and the seasonal nature of their production, in some west African countries (Benin and Nigeria) yams are processed into flour using a well established method. Tubers are peeled, sometimes sliced, blanched in hot water (around 65 °C for 15–50 min) and sun-dried (Akissoé, Hounhouigan, Bricas, Vernier, Nago, & Olorunda, 2001). The resulting dried tubers or chips are then milled into flour, which is used to make a thick paste known as "amala" with a different sensory quality from that of pounded yam (Ajibola, Abonyi, & Onayemi, 1988). The main quality attributes of amala are texture and colour (Hounhouigan, Kayode, Bricas, & Nago, 2002), which may be affected by yam cultivar characteristics and/or by processing conditions.

The flesh of the yam species used is white, whereas the colour of the processed flour ranges from creamy white to dark brown. The discoloration phenomenon has long been studied on fresh tubers and has mainly been associated with enzymatic browning, due to the action of polyphenoloxidase (Almenteros & Del Rosatio, 1985; Ozo, Caygill, & Coursey, 1984) and peroxidase (Asemota, Wellington, Odutuga, & Ahmad, 1992) and to the production of polyphenols and derived products (Osagie & Opoku, 1984). Various phenolic constituents have been reported to be responsible for the discoloration of edible yams: catecholamine was first suspected (Franklin & Ruth, 1972), then cyanidin-3-glucoside (Imbert & Seaforth, 1968; Rasper & Coursey, 1967), while Ozo et al. (1984) reported (+)catechol and procyanidin oligomers as contributing to the discoloration of *D. alata* (Ozo et al., 1984). In the case of dried yam flour and amala, Mestres, Dorthe, Akissoé, and Hounhouigan (2002) reported a close positive correlation between the amala brown index and the total phenol content of the flour. Izundu (1995), on the other hand, pointed out the role of peroxidase in amala browning. The actual contribution of polyphenoloxidase and peroxidase to amala discoloration is, however, still unknown: polyphenoloxidase activity can

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be partly inactivated during blanching at 65 °C (Ozo & Caygill, 1985), and polyphenoloxidase and peroxidase activities are nearly nil in yam flour (Mestres et al., 2002).

In addition, changes in pasting properties, occurring during blanching and drying, have not been fully investigated, although they have been identified as an essential and critical stage of yam chip processing (Akissoé et al., 2001; Ige & Akintunde, 1981).

The aim of this work was to assess the changes in colour and pasting behaviour occurring during blanching and drying, using various yam cultivars, and to investigate the physicochemical bases for these changes.

2. Material and methods

2.1. Plant material

Eight cultivars of *Dioscorea cayenensis-rotundata* (*Baniouré*, *Deba, Gnidou, Kagourou*, *Porchekbim, Tam-sam,Terlunto*, *Yakarango*) were obtained from the International Institute of Tropical Agriculture (IITA-Benin). According to farmers, five of them (*Deba, Kagourou, Porchekbim, Tam-sam, Yakarango*) are very suitable for processing into dry yam chips, two (*Baniouré, Gnidou*) are very unsuitable and one (*Terlunto*) is moderately suitable (Dansi, 2001). The yam tubers were harvested in the first half of December 2000 and processed 1 week after harvesting.

2.2. Experimental design

The tubers (5–7 for each cultivar) were hand-peeled in a water bath (28–30 °C) and sliced into 30 mm thick cylinders using a cutting box. One sample of slices (referred to as A) was freeze-dried and used as a control to assess the physicochemical characteristics of the raw material. The remainder (B) was blanched in a thermostat-controlled water bath set at 65 °C for 20 min, then equilibrated in water at 28–30 °C for 5 min. The blanched slices were divided into two groups (B1 and B2). Group B1 was freeze-dried and used to assess the effect of blanching. Group B2 was dried in a forced air oven at 40 °C for 5 days to assess the effect of drying. Each group (A, B1, B2) was crushed in a mortar, then ground in a laboratory centrifuge mill (Retsch, Haan, Germany) fitted with a 0.2 mm screen. The flour was then stored at 4 °C until analysis.

2.3. Methods

2.3.1. Physicochemical characterization of fresh tubers

The fresh tubers were weighed, their dimensions were measured with a Vernier caliper and their volume was determined by millet displacement. In each case, a mean value was calculated for eight tubers of each cultivar. The dry matter content of the fresh tubers was measured after drying 10 g yam pieces at 105 °C for 48 h. The mean value of three tubers of each cultivar was calculated.

2.3.2. Polyphenoloxidase (PPO) and peroxidase (POD) activity and total phenol (TP) content

PPO, POD and TP were determined using the methods described by Mestres et al. (2002), measuring the oxygen consumption kinetic at 460 nm with catechol as substrate and the discoloration kinetic with an optical density at 760 nm after reaction with Folin reagent.

2.3.3. Hunter Lab colour coordinates

The colour of the flours and the pastes (obtained with a Rapid Visco Analyser as described below) was measured using a Minolta CR-210 portable chromameter (illuminant D65 CIE 1976). The Hunter Lab colour coordinate system L^*, a^* and b^* values were recorded and the brown index was calculated as (100-L^*).

2.3.4. Pasting behaviour

Pasting properties were determined using a Rapid Visco Analyser (RVA, Newport Scientific, Narrabeen, Australia) on 8% dry matter suspension. The suspension was heated from, 35 °C to 95 °C at a rate of 6 °C min^{-1}, maintained at 95 °C for 4 min then cooled to 50 °C at the same rate. Viscosity at the start of the 95 °C plateau (V95b), viscosity at the end of the 95 °C plateau (V95e) and end viscosity after cooling to 50 °C (V50) were measured.

2.3.5. Swelling power and solubility

The swelling power and solubility procedures described by Mestres, Nago, Akissoë, and Matencio (1997) were modified, with a dry matter concentration of 4% (wb; 1.2 g of dry matter dispersed in distilled water to give a total mass of 28 g) being used. The suspension was heated from 35 °C to 95 °C at a rate of 6 °C min^{-1} and held at 95 °C for 1 min using the RVA. The heated suspension was then centrifuged at 3000 *g* for 15 min at ambient temperature.

2.3.6. Thermal behaviour

Amylose content and starch gelatinization properties were determined by differential scanning calorimetry on a Perkin Elmer DSC7 device (Perkin-Elmer, Norwalk, USA), as described by Mestres, Matencio, Pons, Yajid, and Fliedel (1996) and Mestres, Boungou, Akissoë, and Zakhia, (2000).

2.4. Statistical analysis

Analysis of variance and correlation and regression analyses were performed using Statitcf software (ITCF, Boigneville, France).

3. Results

3.1. Physicochemical characterization of fresh tubers

Dry matter content ranged from 24.9 to 32.1% (wb, Table 1). There was great heterogeneity in the weight and size of the fresh tubers: volume ranged from 202 ml for Tamsam to 955 ml for Gnidou. It should be noted that the lowest-rated cultivars (Banioure and Gnidou) had the largest tubers, at least twice the size of the others.

3.2. Contrasting behaviour of polyphenoloxidase and peroxidase activities and total phenols during yam chip processing

Polyphenoloxidase (PPO) and peroxidase (POD) activities and total phenol (TP) content varied to a large extent with cultivar and unit operation (Tables 2 and 3). Fresh Gnidou and Banioure cultivars (cvs) showed contrasting behaviour for PPO and POD activities: Gnidou gave the highest values of PPO activity and Banioure the lowest, and conversely for POD activity. However, other cultivars (Porchekbim and Terlounto) had simultaneous high values of PPO and POD activities. PPO and POD showed contrasting behaviour, depending on the unit operation: POD activity was significantly reduced during blanching (78% reduction in POD activity) whereas PPO was mainly reduced during drying. After drying, residual PPO and POD activities were at least one tenth of initial activities. TP content, on the other hand, increased significantly during drying (twice the initial value, Table 4) but did not vary significantly with cultivar.

Flour obtained after blanching and oven-drying had colour index mean values of 25, −0.8 and 17 for the brown, red and yellow indices respectively. After cooking, pastes had colour index mean values of 54, 0.5 and 10. Amala is indeed a greyish paste, and the brown index is the most representative colour index (Mestres et al., 2002). There was a significant correlation between

Table 1
Physicochemical characteristics of yam cultivars

Yam cultivars (local name)	Dry matter (% wb)	Weight (g)	Volume (ml)	Length (cm)	Head-diameter (cm)	Tail-diameter (cm)
BanIouré	27.4	725	830	34.3	6.3	5.9
Deba	26.3	381	385	23.0	4.3	4.1
Gnidou	28.3	1150	955	31.7	6.3	6.2
Kagourou	32.1	468	464	24.3	4.8	4.1
Porchekbim	30.3	313	324	20.7	4.8	3.8
Tam-sam	24.9	182	202	19.7	2.9	3.3
Terlounto	29.6	454	439	22.0	5.5	5.0
Yakarango	26.5	338	366	17.5	5.2	4.8

Table 2
Effect of processing stage and yam cultivar on polyphenol oxidase activity (μmol O^2 min^{-1} g^{-1})

	Freeze-dried		Oven-dried
Yam cultivars (local name)	Fresh slices	Blanched slices	Blanched slices
Banioure	10.4	10.2	1.2
Deba	32.2	19.8	0.6
Gnidou	72.6	51.4	3.7
Kagourou	35.7	24.7	2.5
Porchekbim	59.5	42.5	4.5
Tam-sam	13.6	11.0	1.1
Terlunto	33.2	25.6	1.2
Yakarango	25	21.8	2.8
Mean[a]	35.2a	25.9a	2.2b
Cultivar effect		**	
Single unit operation effect		**	
Standard error of residual		10.0	

[a] Mean values with same letter belong to same homogeneous group at 5% level.

** Significant at 1% level.

Table 3
Effect of processing stage and yam cultivar on peroxidase activity (mDO s^{-1} g^{-1})

	Freeze-dried		Oven-dried
Yam cultivars (local name)	Fresh slices	Blanched slices	Blanched slices
Banioure	384	45	5
Deba	148	49	28
Gnidou	119	98	50
Kagourou	143	47	43
Porchekbim	286	29	13
Tam-sam	269	25	12
Terlunto	276	47	20
Yakarango	187	48	6
Mean[a]	226 a	49 b	22 b
Cultivar effect		ns	
Single unit operation effect		**	
Standard error of residual		61	

[a] Mean values with same letter belong to same homogeneous group at 5% level.

** Significant at 1% level ns, non significant.

Table 4
Effect of processing stage and yam cultivar on total phenolic content (μM g^{-1} db)

Yam cultivars (local name)	Freeze-dried Fresh slices	Freeze-dried blanched slices	Oven-dried blanched slices
Banioure	2.0	1.4	10.7
Deba	1.2	2.0	2.6
Gnidou	2.3	2.8	3.0
Kagourou	2.0	2.2	1.9
Porchekbim	2.3	3.0	5.2
Tam-sam	2.9	3.1	9.1
Terlunto	2.3	2.6	3.5
Yakarango	2.3	2.6	2.4
Mean[a]	2.2 b	2.5 b	4.8 a
Cultivar effect		ns	
Single unit operation effect		*	
Standard error of residual		2	

[a] Mean values with same letter belong to same homogeneous group at 5% level.
*Significant at 5% level ns, non significant.

Table 5
Browning index of paste from yam cultivar at different processing stages

Yam cultivars (local name)	Freeze-dried Fresh slices	Freeze-dried blanched slices	Oven-dried blanched slices
Banioure	35.0	32.9	63.0
Deba	54.0	54.6	54.8
Gnidou	49.2	39.0	48.4
Kagourou	43.4	43.4	47.9
Porchekbim	44.7	40.7	60.9
Tamsam	40.5	44.1	61.6
Terlunto	38.4	39.0	52.2
Yakarango	47.7	41.3	43.0
Mean[a]	44.1 a	41.9 a	54.0 b
Cultivar effect		ns	
Single unit operation effect		**	
Standard error of residual		6.6	

[a] Mean values with same letter belong to same homogeneous group at 5% level.
** Significant at 1% level ns, non significant.

the brown index of flour and that of corresponding amala. Because of this, mainly the brown index of amala will be discussed. The brown index did not vary significantly with the yam cultivar used (Table 5). However, it increased significantly with drying (from 41.9 to 54.0 for the cultivar mean value) whereas blanching had no significant effect. A correlation was observed between the brown index of amala and the total phenol content of the oven-dried flour ($r=0.84$, Table 6) and between the brown index of amala and the peroxidase activity of the fresh freeze-dried flour ($r=0.75$). In contrast, the yellow index of amala decreased when the total phenol content of oven-dried flour and the peroxidase activity of fresh freeze-dried yam increased. No significant correlation was found between PPO activity and the flour or amala colour indeics.

3.3. Effect of blanching and drying on yam starch characteristics

Amylose content was not affected by either unit operation but varied significantly with yam cultivar. Three groups were distinguished: Banioure, with the lowest amylose content (16.6% db), Gnidou, with the highest (22.5% db), and the other cultivars, with amylose contents of between 18.0 and 20.3% db. The starch gelatinization onset temperature was significantly affected by unit operations (Table 7). Oven-dried yam slices had a higher onset temperature than freeze-dried samples (mean values: 74.5 °C and around 72 °C, respectively). The cultivar effect was significant only at the 10% level. Banioure cv had the highest value (74.5 °C) and Terlunto the lowest (71.0 °C). On the other hand, neither blanching at 65° C for 20 min nor drying at 40 °C for 5 days significantly affected gelatinization enthalpy, which had a mean value of 12.1 J g^{-1} DM.

All viscosity parameters (V95b, V95e, V50) were closely correlated (Table 8) and results for paste viscosities at 50 °C (V50) will be mainly discussed. Oven-drying lowered V50 significantly (from 154 RVU to 77 RVU, Table 9) whereas blanching had no significant effect. Some cultivars appeared more sensitive to this change than others (the oven-dried Banioure end viscosity was

Table 6
Correlation between colour indexes of amala and some biochemical characteristics of yam flours

	Polyphenol oxidase activity of flour			Peroxidase activity of flour			Total phenol content of flour		
	Fresh Freeze-dried	Blanched Freeze-dried	Blanched Oven-dried	Fresh Freeze-dried	Blanched Freeze-dried	Blanched Oven-dried	Fresh Freeze-dried	Blanched Freeze-dried	Blanched Oven-dried
100-L	−0.29	−0.32	−0.25	0.75*	−0.53	−0.45	0.11	−0.12	0.84**
a	−0.16	−0.28	−0.47	0.05	−0.21	0.15	−0.41	−0.27	0.33
b	0.45	0.41	0.03	−0.86**	0.70	0.77*	−0.31	0.09	−0.85**

* Significant at 5% level.
** Significant at 1% level.

Table 7
Gelatinization properties of fresh freeze-dried and blanched freeze- and oven-dried yam slices

Yam cultivars (local name)	Onset temperature (°C)			Enthalpy change (J g^{-1} db)		
	Fresh freeze-dried	Blanched freeze-dried	Fresh oven-dried	Fresh freeze-dried	Blanched freeze-dried	Blanched oven-dried
Banioure	74.5	73.9	75.0	12.7	12.8	10.9
Deba	72.2	72.8	74.7	11.7	10.8	11.3
Gnidou	73.4	72.8	73.7	11.9	11.4	12.8
Kagourou	71.5	71.6	74.6	12.5	12.8	13.5
Porchekbim	71.9	72.9	74.3	10.8	11.2	11.2
Tam-sam	71.5	73.2	74.3	12.2	11.9	9.6
Terlunto	71	72.7	73.7	12.9	13.3	12
Yakarango	71.6	72.9	75.4	11.8	13.5	14.4
Mean[a]	72.0 b	72.8b	74.5a	12.1	12.2	12
Cultivar effect		ns			ns	
Single unit operation effect		**			ns	
Standard error of residual		0.7			0.9	

[a] Mean values with same letter belong to same homogeneous group at 5% level.
* Significant at 1% level ns, non significant

Table 8
Correlation between starch physicochemical properties and viscosity of amala

	V95b	V95e	V50	Amylose content	Enthalpy change	Onset	Swelling
V95b	1						
V95e	0.95***	1					
V50	0.96***	0.99***	1				
Amylose content	0.05	0.03	0.04	1			
Enthalpy change	0.13	0.18	0.18	0.36	1		
Onset	0.34	0.32	0.31	−0.08	0.01	1	
Swelling	0.81***	0.78***	0.80***	0.05	−0.05	0.03	
Solubility	0.01	−0.11	−0.10	−0.16	−0.50*	0.03	0.21

* Significant at 5% level.
*** Significant at 0.1% level.

one tenth of that of the freeze-dried sample, whereas that of Yakarango, in particular, did not vary greatly with processing).

Both cultivar and processing were observed to have a significant effect on the swelling power and solubility of yam flour during pasting (Table 10). Kagourou had the highest swelling power and Banioure and Tamsam the highest solubility. Oven-drying drastically reduced swelling power. Swelling power was significantly and positively correlated with the viscosity variables (Table 9): the correlation coefficient was, for example, 0.80 between swelling power and V50 (Fig. 1). Multiple regression analysis showed that swelling power and solubility could explain 71% of the variability in end viscosity, V50, (Fig. 2) according to the model:

$$V50_{calculated} = 4.0 + 17.9 \times \text{swelling power} - 8.7 \times \text{solubility}.$$

Table 9
End viscosity (V50, RVU) of paste from yam cultivars at different stages of processing

Yam cultivars (local name)	Freeze-dried		Oven-dried
	Fresh slices	Blanched slices	Blanched slices
Banioure	164	150	16
Deba	150	145	77
Gnidou	163	156	73
Kagourou	130	194	156
Porchekbim	140	89	20
Tamsam	149	145	27
Terlunto	161	200	106
Yakarango	152	150	142
Mean[a]	151 a	154 a	77 b
Cultivar effect		ns	
Single unit operation effect		**	
Standard error of residual		33	

[a] Mean values with same letter belong to same homogeneous group at 5% level.
*Significant at 1% level ns, non significant.

Table 10
Swelling power and solubility of yam flours at different processing stages

Yam cultivars (local name)	Swelling power ($g\ g^{-1}$)			Solubility ($mg\ ml^{-1}$)		
	Fresh freeze-dried	Blanched freeze-dried	Blanched oven-dried	Fresh freeze-dried	Blanched freeze-dried	Blanched oven-dried
Banioure	13.4	12.8	8.7	13.1	14.0	12.9
Deba	13.1	12.1	7.6	11.2	12.1	11.2
Gnidou	13.3	14.2	9.8	11.0	10.7	7.3
Kagourou	15.5	14.8	11.5	12.9	9.8	8.9
Porchekbim	15.8	14.4	8.6	12.9	9.8	11.6
Tam-sam	13.5	13.3	8.8	13.1	13.8	12.9
Terlunto	13.3	15.2	10.4	12.2	12.9	11.2
Yakarango	13.5	14.5	11.4	11.5	13.1	8.9
Mean[a]	14.1 a	13.9 a	9.6 b	12.3	12.1	10.6
Cultivar effect		*			*	
Single unit operation effect		**			*	
Standard error of residual		0.9			1.3	

[a] Mean values with same letter belong to same homogeneous group at 5% level.
** Significant at 1% level.
* Significant at 5% level

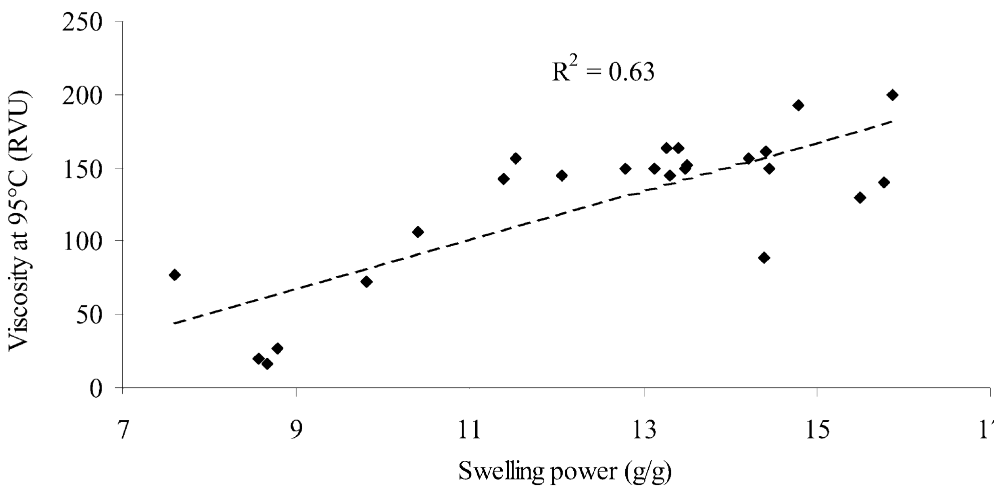

Fig. 1. Relation between viscosity at the start of the 95 °C plateau and swelling power.

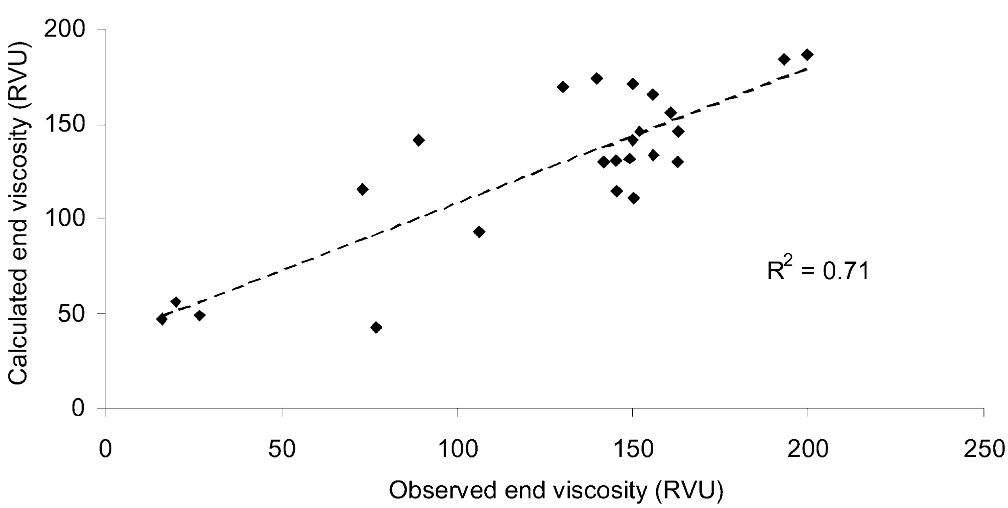

Fig. 2. Relation between observed and calculated end viscosity.

5. Discussion

PPO and POD activities of the fresh freeze-dried samples were within the range reported by Mestres et al. (2002): 10–50 μmol O_2 min^{-1} g^{-1} and 60–600 mDO s^{-1} g^{-1}. The lack of effect of blanching at 65 °C for 20 min on PPO activity was consistent with results of Ikediobi & Obasuyi (1982) and Yang, Fujita, Ashrafuzzaman, Nakamura and Hayashi (2001a, 2001b), who showed that 80% of PPO activity remained after 10 min at 70 °C and that PPO was stable at 60 °C for up to 30 min. In contrast, PPO activity decreased dramatically after oven-drying at 40 °C for 5 days. This was in agreement with results of Omidiji and Okzupor (1996) and of Ikediobi and Obasuyi (1982), who revealed that PPO activity fell drastically after storage at 40 °C for 4–12 h or at room temperature for 2 weeks. This must be linked to a long-term PPO degradation mechanism. On the other hand, POD appeared sensitive to heat and was almost completely inactivated after 20 min at 65 °C.

The total phenol content of the oven-dried samples was slightly higher than the values (0.5–2.5 μmol g^{-1} db) obtained by Mestres et al. (2002). Total phenol content increased during drying (Table 4). During this operation, peroxidase activity was low (between 49 mDO $s^{-1}g^{-1}$ at the start of drying and 22 mDO $s^{-1}g^{-1}$ at the end of drying, Table 3) while PPO activity decreased dramatically (from 25.9 μmol O_2 $min^{-1}g^{-1}$ to 2.2 μmol O_2 $min^{-1}g^{-1}$, Table 2). This tends to indicate that phenol production was not dependent on enzymatic activity. However, the phenol content of the oven-dried flour was highly and positively correlated with the POD activity of the fresh tubers (Table 6). This suggests a two-step reaction mechanism, leading to an increase in the total phenol content of yam flour. The first step, occurring before blanching is completed, would be mainly POD-dependent and lead to phenol precursors, while the second, occurring during drying, would be a long-term non-enzymatic phenomenon. A similar scenario was observed with the brown index of flour and amala. This is partly consistent with the results of Omidiji and Okpuzor (1996), who showed that yam browning was partly enzymatic (40%) and partly non-enzyme-mediated. However, these authors worked on fresh tubers and PPO activity. In any event it appears clear that the browning of amala is linked to the total phenol content of the flour ($r = 0.84$), which is dependent on POD activity in the fresh tubers ($r = 0.75$), while PPO activity was not found to be significantly involved. In addition, the increase in discoloration when flour is being cooked to prepare amala should be linked to thermal degradation of originally colourless complex phenolics (proanthocyanidins and lignins) to coloured phenols (anthocyanidins, Swain and Hillis, 1959).

The stability of starch gelatinization enthalpy during processing is consistent with the low blanching temperature (65 °C) in comparison to the high gelatinization temperature of yam starch (72 °C). However, the lack of gelatinization during laboratory blanching at 65 °C is in contradiction with the 35% gelatinized starch measured in yam flour sold in the markets (Akissoé et al., 2001), which is normally processed at the same temperature. This shows the great variation in blanching temperature in the production of traditional yam flour for market. The stability of the amylose content during processing indicates that there is no significant leaching of amylose during blanching, probably due to lack of gelatinization. The increase in the onset temperature during drying must be linked to starch annealing, which can be observed after starch has been steeped for several hours at 55 °C or for several days at 35 °C (Nakazawa, Noguchi, Takahashi & Takada, 1984; Mestres et al., 2000). Annealing is a long-term water-dependent phenomenon that can occur during the first step of drying at 40 °C for 5 days. At the same time, annealing can explain the low swelling power and solubility of the dried samples.

Amala viscosity depends first on swelling power and second on solubility (Table 8 and Figs. 1 and 2). This confirmed previous results obtained by Mestres et al. (1997) on maize paste. Hence, amala viscosity decreases after oven-drying at the same time as swelling power decreases due to starch annealing. Starch swelling power and solubility also play determinant role in the firmness of tô (Fliedel, 1994), a sorghum thick paste with similar texture to amala. This suggests that processing, primarily drying, should have some effect on amala texture. The question will be investigated in further studies.

There is no direct relationship between cultivar ratings by farmers and objectively measured parameters such as the brown index and paste viscosity of amala. The lowest-rated cultivars (Banioure and Gnidou) had no particular behaviour associated with these parameters (Tables 5 and 8). They do, however, have the largest tubers (Table 1), and this may well make drying long and hard when traditional sun-drying is involved. The problem was not apparent in our study as the tubers were cut into 30 mm thick slices.

Finally, this study showed the effectiveness of blanching in reducing POD activity and hence the browning potential of the product, although product stabilization by long-term drying induces non-enzymatic browning. Long-term drying additionally leads to a lower pasting viscosity and probably also affects amala texture.

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